Illinois Department of Transportation
2300 South Dirksen Parkway / Springfield, Illinois / 62764

BDE PROCEDURE MEMORANDUM

NUMBER: 34-06

SUBJECT: Impact Attenuators (Crash Cushions)

DATE: April 21, 2006

The information herein replaces Section 38-8 in the BDE Manual. This memorandum supersedes BDE Procedure Memorandum 34-04, effective for projects on the August 2006 and subsequent lettings.

Background

Previous IDOT applications of impact attenuators (crash cushions) were designed to various performance standards. Current FHWA policy requires that all roadside safety hardware used on National Highway System (NHS) Routes be accepted under National Cooperative Highway Research Program Report 350 (NCHRP 350) criteria. This memorandum updates Section 38-8 of the BDE Manual to list and give guidance on application of impact attenuator hardware that is accepted by the FHWA under NCHRP 350.

Applicability

The following procedures are applicable to all projects on the State highway system, effective August 1, 2006. (Also, any items used on a case-by-case basis shall comply with the appropriate NCHRP 350 criteria.)

Generally, the devices listed herein are accepted at Test Level 3 under the NCHRP 350 criteria. When the design speed is 45 mph (70 km/hr) or less (including work zones with reduced speed limits), the designer may consider specifications for devices accepted at Test Level 2. Contact the Bureau of Safety Engineering for further information.

Procedures

General

Impact attenuators (crash cushions) are protective systems that prevent errant vehicles from impacting hazards by decelerating them to a stop after a frontal impact, by redirecting them away from the hazard, or by decelerating them after a side impact. They operate on the basis of either energy absorption or momentum transfer. Impact attenuators are adaptable to many roadside hazard locations where longitudinal barriers cannot practically be used.

Warrants

Regardless of median width, all piers, sign foundations, and similar hazards in medians of divided highways warrant shielding with an impact attenuator(s), or other systems accepted under NCHRP 350. For extreme median widths (greater than 84 feet), exceptions should be considered on a case-by-case basis.

Impact attenuator warrants are the same as barrier warrants. Once a hazard is identified, the designer should first attempt to remove, relocate, or make the hazard breakaway. If the foregoing is impractical, then an impact attenuator should be considered.

Impact attenuators serve two principal functions. They may be installed as stand-alone devices to shield point hazards such as bridge piers or sign foundations, or they may be used as terminal treatments for roadside or median barrier systems. When used to shield a point hazard, the impact attenuator is placed very near or in contact with the hazard, thus no length of need applies, and no additional barrier is required. This can only be done where the shoulder and/or foreslope in the runout area is 10:1 or flatter, and other aspects of the required impact attenuator layout (pad or base, physical room for the system, etc.) can be accommodated. Otherwise, a roadside barrier or median barrier, as appropriate should be used. An impact attenuator, or other NCHRP 350 approved terminal treatment will then be needed for the barrier.

Impact Attenuator Types

Overview

Selection of the most appropriate impact attenuator type depends on a variety of factors.

The impact attenuator devices have various properties related to the path of a vehicle after impact. These are called the *redirective properties*.

Also, the various systems have varied means to deal with the energy or momentum imparted by an impact. These are called the *operational principles.*

Some systems retain residual capacity to absorb additional frontal impacts during the time between an initial crash and full repair of the system. Systems vary in the cost and effort required for repair of crash and nuisance hits. These are considered as *maintenance and repair issues*.

To be considered for use on Illinois highways, a given device must be on the Department's approved list. This issue is addressed under *device approval status*.

The size, layout, and anchorage requirements may dictate or eliminate various systems depending on the type of location where protection is required.

These requirements are grouped together for consideration as *physical placement requirements.*

Given the wide variation in the approaches to the above considerations, the systems vary in *cost* of installation and repair. Life cycle cost analysis using the Roadside Safety Analysis Program (RSAP) may also be a useful tool.

In some installations, impact attenuators may be introduced into the *pedestrian/bicyclist environment*. This will require consideration of various factors to evaluate the relative risks to the vehicular traffic and pedestrian/bicyclist traffic.

All of these factors, taken together will guide the *impact attenuator selection*.

Redirective Properties

A vehicle is redirected when it safely stays on the same side of the item it strikes. NCHRP 350 provides further criteria to define safe redirection.

1. Fully Redirective Devices

   A fully redirective device will safely redirect a vehicle that impacts at any location along the face of the device.

2. Partially Redirective Devices

   A partially redirective device will safely redirect a vehicle that impacts downstream of a given length of need point along the length of the device. This type of device will allow a vehicle impacting between the length of need point and the free end of the impact attenuator to pass through to the area behind the device.

3. Non-Redirective Devices

   A non-redirective device will either capture an impacting vehicle or allow it to pass through when hit along the face of the device.

Operational Principles

1. Energy Absorbing Devices

   This type of impact attenuator operates on the principle of absorbing the energy of the vehicle by various means, including crushing or deformation of engineered modules, or by compression of a hydraulic cylinder. Some energy is also absorbed by the impacting vehicle as the front end of the vehicle is crushed on impact. Energy absorbing attenuators require rigid back-up support or connection to another barrier system to contain the forces created by the deformation of the device. This support may be supplied as part of the impact attenuator, or may be derived from its connection to the barrier or hazard (such as a concrete structure). This distinction may preclude the use of some system for shielding point hazards which will not provide this support. In such cases, a Special

Provision limiting the selection to no less than two alternatives may be required. This type of device also requires vertical and lateral anchoring. This is accomplished by attachment to a bituminous or concrete base, or by placement of posts. Devices of this type capture or rebound the vehicle in a frontal impact. For side impacts, the devices work either as fully redirective or partially redirective.

2. Momentum Transfer Devices

This type of system operates by transferring the momentum of an impacting vehicle to an expendable mass of material contained in the device. A typical device of this type is an array of sand-filled plastic modules. Sand module configurations meeting NCHRP 350 requirements are available to accommodate various speeds and widths. However, arrays with only one row of barrels are not approved for use by IDOT. Information is available from the various manufacturers regarding their NCHRP 350 accepted configurations.

The sand module systems require no back-up support or connection to another system. However, they do require that the modules be placed on a bituminous or concrete base. Sand modules have no redirective capability and generate considerable debris upon impact. On a corner with approaching traffic, the exterior modules must be laterally offset at least 2.5 ft (750 mm) from the corner of the hazard (Figure 1.)

The sand module impact attenuator design should allow for safe side impacts. Figures 1 and 2 illustrate two methods to modify the sand module design to accommodate angle impacts. Figure 1 illustrates how the modules may be shifted to afford attenuation at the end points and direction along the sides of the hazard by closing or covering the gap between pier columns. Figure 2 illustrates where the side of the hazard and available space are such that full protection, through attenuation only, can be provided by the use of additional modules to widen the standard array. Although the entire area of the hazard must be shielded from angle impacts either by attenuation or redirection, the permissible attenuation may be varied to optimize space and economy. The layout of the sand module arrays should be as accepted under NCHRP 350, or designed to meet those criteria.

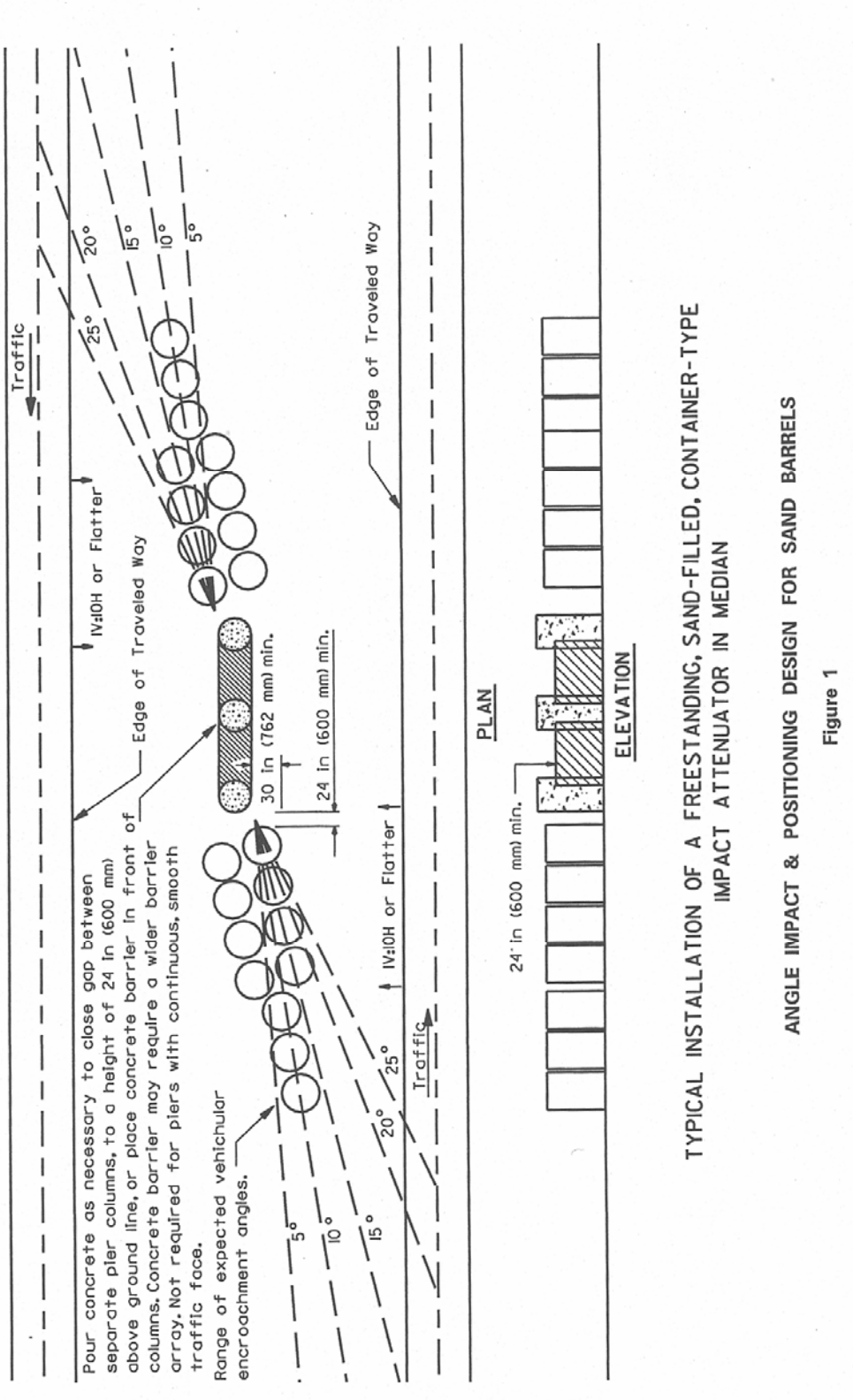
The specific layout of sand modules, including positioning relative to the hazard shall be included in the plans. It shall note the Test Level for which the array is designed.

Another type of system listed in this category is the water filled impact attenuator.[1] Water filled impact attenuators also have no redirective capability and may spread water in the area of an impact. These impact attenuators are used with temporary barriers, and must be attached to the barrier system. They do not require anchorage to the pavement or base.

Water filled impact attenuators require less width for placement than do sand module impact attenuators.

Figure 3 gives comparisons of systems based on their operational principles.

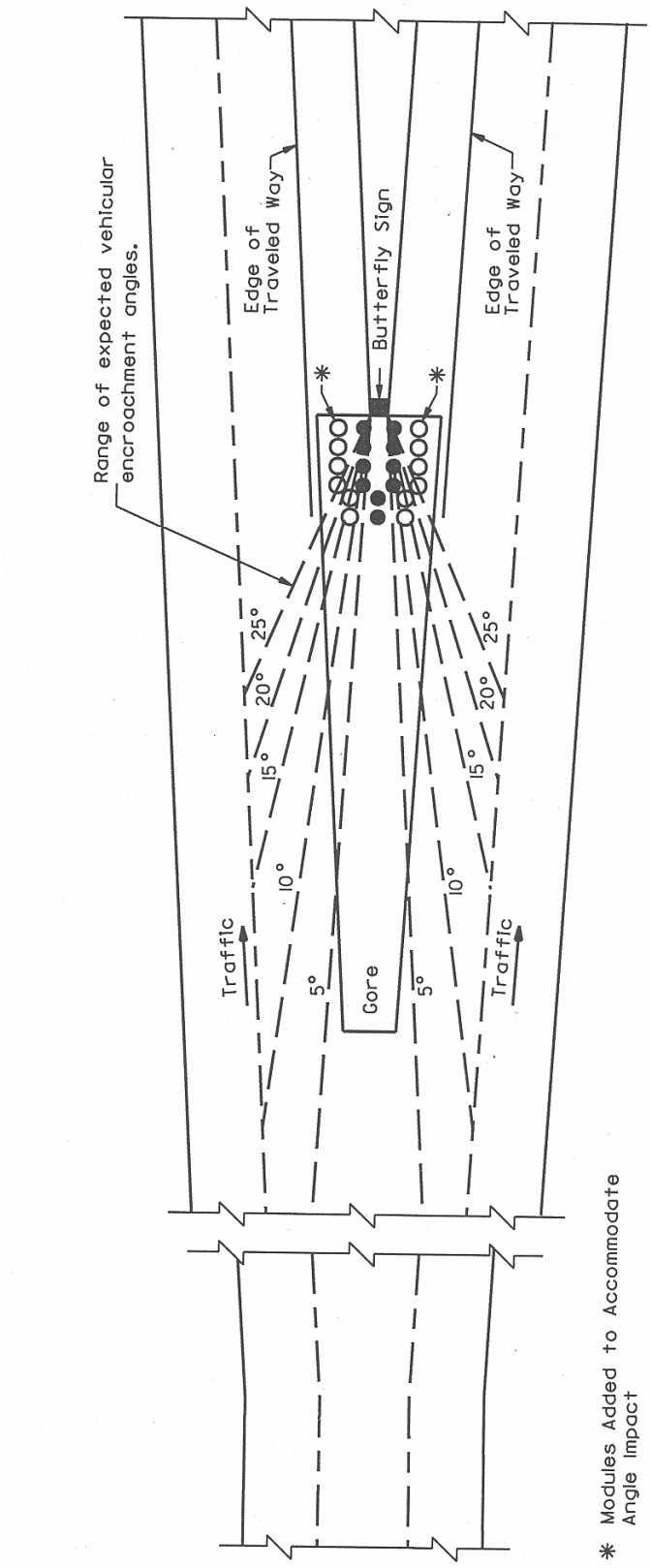
[1] The water-filled barrier dissipates energy both by energy transfer (crushing of modules) and by momentum transfer to the system's mass.



TYPICAL INSTALLATION OF A FREESTANDING, SAND-FILLED, CONTAINER-TYPE IMPACT ATTENUATOR IN MEDIAN

ANGLE IMPACT & POSITIONING DESIGN FOR SAND BARRELS

Figure 1



TYPICAL INSTALLATION OF A FREESTANDING, SAND-FILLED, CONTAINER-TYPE IMPACT ATTENUATOR SYSTEM IN A MAJOR FORK

ANGLE IMPACT DESIGN FOR SAND BARRELS

Figure 2

Comparison by Operational Principle

OPERATIONAL PRINCIPLE	ADVANTAGES	DISADVANTAGES
Energy Absorbing Devices	1. Little or no debris after a hit. 2. Ease of maintenance after a hit. 3. Some systems retain partial attenuation capacity after a hit. 4. Relatively low maintenance cost to repair after a hit. 5. Protection from pocketing at transition from impact attenuator to hazard. 6. Adaptable to very narrow hazards.	1. Possible high initial costs. 2. Considerable site preparation. (Pad, back-up structure, mounting bolts or anchors.) 3. IDOT pay items and specifications will cover hazards up to only 90 inches wide. See discussion in "Physical Placement Requirements", under "Transitions."
Momentum Transfer Devices (Sand Modules)	1. Relatively low initial cost. 2. Ease of installation. 3. Versatile; can be used to cover a large area.	1. Considerable debris after a unit is hit. 2. Relatively high maintenance cost to repair after a hit. 3. Generally, no residual attenuation capacity after a major hit. 4. No side redirection and little or no protection at transition from impact attenuator to hazard. 5. Considerable inventory of parts and space for replacements required. 6. Modules may "walk" when placed on structures. (Contact BDE if this application is required.)
Momentum Transfer Devices (Water Filled)	1. Relatively low initial cost. 2. Ease of installation 3. Little or no site preparation. 4. Does not require anchorage to a paved base. 5. Adaptable to very narrow hazards. 6. After impact, can be restored quickly by two laborers and a water supply/tank.	1. Water on ground or pavement immediately after a hit. 2. Requires environmentally friendly antifreeze for cold weather application. 3. Attaches only to concrete barrier, although the barrier may transition then to other systems. 4. Generally, no residual attenuation capacity after a major hit. 5. No side redirection. Must be placed beyond the length of need point. 6. Modules may "walk" when placed on cross-sloped structures. (Contact BDE if this application is required.)

Figure 3

Maintenance and Repair Considerations

Some systems require extensive repairs or replacement after a full speed impact, while some others may only require minor adjustments and/or replacement of drop-in modules or simply resetting with minimal repair parts. Additionally, some systems retain partial capability to shield a hazard after an initial impact and before repair.

Sand modules are particularly vulnerable to nuisance hits from mowers or wide vehicles. Such occurrences may puncture the plastic modules and cause loss of sand, thus rendering the devices ineffective. Care should be taken to provide some buffer space on the pad for sand modules to allow for mower overhang. A minimum suggested buffer is 12 inches (300 mm) along the sides and front of the array.

Impact attenuators that incorporate tracks or guides anchored to a base may be subject to accumulation of road debris such as sand and silt. In extreme cases and conditions these may interfere with the operation of the attenuator. Generally, attenuator locations should be kept out of depressed locations or other sites that encourage deposition of debris. When this is unavoidable, the designer may "write out", by Special Provision, any specific impact attenuators that have critical moving parts (tracks, guides, rollers, cables, etc.) near the ground line.

In the following sections, "resettable" devices are those that do not usually require significant repair parts, but may require work to return the system to a crashworthy configuration, ready for the next impact. The first cost for these systems is intermediate between severe use (see below) and other fully-redirective devices. These devices are cost-effective where significant impacts may occur once or more in a three year period. Spreadsheets are available for more detailed analysis, and the designer may contact the Safety Design Engineer (217-785-0720) in the Bureau of Safety Engineering for more information.

There is no specification for wide impact attenuators in the resettable category. This is because the available systems vary in their treatment of this issue. Where a wide hazard is to be shielded with a resettable attenuator, the designer may prepare a special barrier transition from the hazard to the attenuator connection. Refer to the manufacturer's specifications and drawings as well as Chapter 38-6.05 of the BDE Manual.

In the following sections, the term "severe use" is used to indicate installations for which the crash cushion should retain some residual capacity to absorb additional frontal impacts while awaiting repairs and should also require minimum cost and time for repairs after an impact. These installations are those where repeated or frequent hits are known or anticipated, and where lane closures to repair the crash cushion need to be kept to a minimum time window.

The residual frontal impact capacity available in the "Severe Use" items may be offset by some reduction in redirective capability. The residual capacity is not a substitute for proper inspection and repair after each impact. Also, the

elastic components will deteriorate with time and repeated impacts, and will require replacement. Some current indications are that about 13 to 15 impacts may warrant replacement.

Device Approval Status

1. Approved Devices

   For routine use by IDOT, a system must be accepted under NCHRP 350, and be on the Department's approved list. IDOT's approved list is published as a Special Notice in each "Notice of Letting" document published by IDOT. The designer should note that all of the operational systems are proprietary. Contact BDE for additional information on impact attenuator installations. Also, information regarding NCHRP 350 acceptance, crash test results, and descriptive information may be researched through manufacturers' information, and at the FHWA Internet web page at:

   http://safety.fhwa.dot.gov/fourthlevel/hardware/term_cush.htm

   Unless otherwise noted, all items on the Department's approved list of NCHRP 350 devices are crash tested and accepted at Test Level 3. This level of safety is adequate for facilities with speed limits posted greater than 45 mph. For lower speed facilities, the designer may specify the use of devices accepted at Test Level 2. Information relative to Test Level 2 devices is included in Attachment A and in the BDE Special Provisions.

   Also, see Attachment A for a partial review and comparison of attributes of various approved systems.

2. Other Devices

   There are some devices accepted under NCHRP 350 but not listed on the Department's approved list. See the above listed Internet site, the Roadside Design Guide, and the various manufacturers' brochures and Internet sites. A proposed use of these devices must be coordinated with BDE.

   Attachment B correlates the various systems to contract pay items.

Physical Placement Requirements

Several factors should be considered in the placement of an impact attenuator:

1. Level Terrain. All impact attenuators have been designed and tested for level conditions. Vehicular impacts on devices placed on an excessively sloped site could result in an impact at improper height that could produce undesirable vehicular behavior. Therefore, the attenuator should be placed on a base or pavement slightly sloped to facilitate drainage, but the cross slope should not exceed 5%, or as allowed by the proprietary

specifications. Impact attenuators that require anchorage to the base should not be placed over a break in slope, as this can misalign necessary guide rails, and other components.

2. Curbs. No curbs higher than 2 in (50 mm) should be constructed at impact attenuator installations. On existing highways, all curbs higher than 2 in (50 mm) should be removed at proposed installations, if feasible.

3. Surface. Many impact attenuator systems require a paved, bituminous or concrete pad. To minimize nuisance hits, especially for sand module impact attenuators, the total base width should be 2 ft (600 mm) wider than the array.

4. Elevated Structures. The unanchored sand modules or water filled impact attenuators may "walk" due to the vibration of an elevated structure with a cross-sloped surface. This could adversely affect performance. If it is necessary to place sand modules or water filled impact attenuators on elevated structures, contact BDE for assistance.

5. Orientation. The impact attenuator should be oriented to accommodate the probable impact angle of an encroaching vehicle. See Figures 1 and 2 for sand modules. This will maximize the likelihood of a head-on impact. However, this is not as important for impact attenuators with redirective capability. The proper orientation angle will depend upon the design speed, roadway alignment, and lateral offset distance to the attenuator. A maximum angle of approximately 10° toward oncoming traffic, as measured between the highway and impact attenuator longitudinal centerlines, is considered appropriate.

6. Location. The system must not infringe on the traveled way. There should be a minimum of 2 ft (600 mm) behind sand module systems and in front of the hazard to allow access to the system. The space or transition behind other impact attenuator systems should be according to the manufacturer's specifications.

7. Bridge Joints. Avoid the placement of fully or partially redirective impact attenuators over bridge expansion joints or deflection joints in deep superstructures because movement in these joints could create destructive strains on the system's anchor cables or other continuous parts.

8. Transitions. Transitions between systems and backwalls, bridge rails, or other objects are detailed in various proprietary systems, if required. Review the acceptance information and the attached guidance to make sure that systems are approved for bidirectional applications where necessary.

   Many impact attenuators can connect to guardrail or to concrete barrier. In these cases, and when the available length allows, width transitions may be designed using a barrier extended back from the impact attenuator to a connection to or protective position in front of the wide

hazard. The barrier design and flare rates should be according to Chapter 38 of the BDE Manual and IDOT Standards. Keep in mind that any flared barrier or impact attenuator may somewhat increase the redirection angle for impacting vehicles.

Cost

The designer should investigate relative costs for items under consideration. The tabulations herein provide some idea of relative costs. In some cases, a premium for fully redirective properties, for a resettable system, or for items for severe use installations will be offset by the maintenance or repair benefits provided. However, the designer should be careful not to apply premium systems where crash(es) are rare (1 or less expected impact per 10 years). Thus, the tabulations recommend the simpler, lower priced systems for installation in wide medians, for example.

Conversely, use of a low-cost, sacrificial system in an area with occasional (up to 1 crash per 3 years), to frequent impacts (2 or more impacts per year), will lead to high costs for repeated replacement of the attenuator.

Pedestrian/Bicyclist Environment

Impact attenuators are designed to contribute to a forgiving roadside for errant vehicles. The crash testing takes place at 60 mph (nominal) and angles up to 20 degrees for TL-3 and at 45 mph (nominal) and similar angles for TL-2 devices. The impact attenuators developed to buffer such crashes are often constructed of steel panels and frames, cables, steel or wood posts. Also, during an impact, these parts are designed to move, crush, or break in a controlled manner, and the impacting vehicle may rotate, rebound or glance off the impact attenuator.

Placing an impact attenuator in a pedestrian environment imposes compromises and tradeoffs between vehicle occupant safety and pedestrian/bicyclist safety. As much as possible, impact attenuators should be placed away from pedestrian/bicyclist facilities. For example, where an impact attenuator must be located at the end of a parapet or wall crossing a bridge, if space permits, extend the wall or parapet beyond the bridge and separate the pedestrian/bicyclist way from the wall and roadway before introducing the impact attenuator.

It will not always be feasible to provide such ideal conditions. Evaluation of the tradeoffs between vehicular and pedestrian/safety should include factors contributing to the relative risk for each user class. These include exposure of individuals, quality of the design/design constraints, and expected severity of each crash category.

Exposure measures include ADT for vehicular traffic and pedestrian volumes and bicycle ADT for those users.

Measuring the quality of the design includes mainly the offset between the impact attenuator and the roadway and/or pedestrian/bicyclist way along with any constraints on developing this offset.

To evaluate the expected severity of any crashes, consider the operating speed of the roadway facility, the treatment under consideration (impact attenuator, blunt end, sloped end), and the nature of any particular impact attenuators under consideration.

The following table offers comments regarding pedestrian/bicyclist considerations for particular impact attenuators:

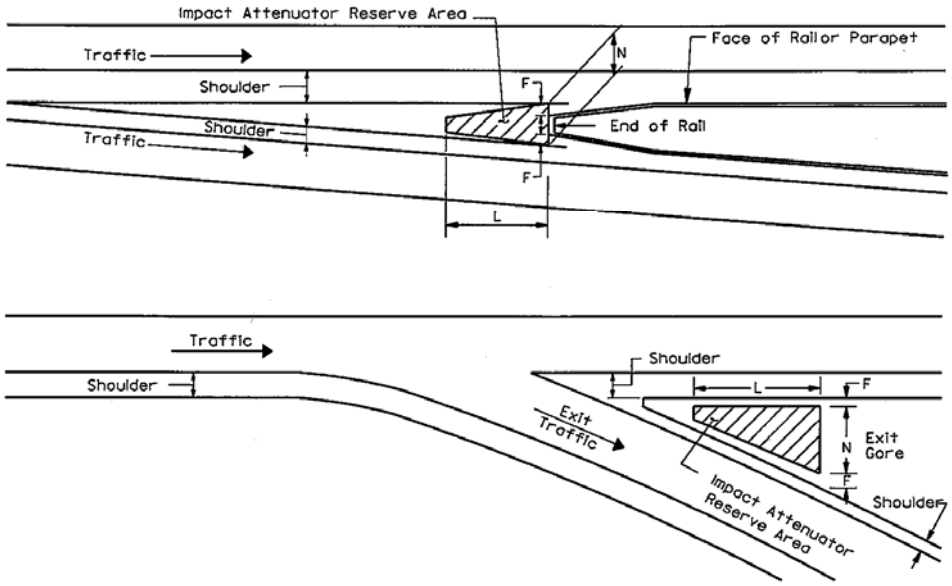
Impact Attenuator System or Family	Pedestrian/Bicyclist Considerations
QuadGuard	Side panels face pedestrians/bicyclists from opposing direction. Gaps should be installed as tight as possible on pedestrian side. Top edge exposed similar to guardrail.
SCI-100GM	Side panels face pedestrians/bicyclists from opposing direction. Exposed edges are beveled and should minimize snagging. Side panels remain nested upon head on impact. Gaps should be installed as tight as possible on pedestrian side. Top edge exposed similar to guardrail.
TRACC	Side panels face pedestrians/bicyclists from opposing direction. Gaps should be installed as tight as possible on pedestrian side. Top edge exposed similar to guardrail.
TAU-II	Side panels face pedestrians/bicyclists from opposing direction. Gaps should be installed as tight as possible on pedestrian side. Top edge exposed similar to guardrail.
QUEST	Side panels face pedestrians/bicyclists from opposing direction. Gaps should be installed as tight as possible on pedestrian side. Top edge exposed similar to guardrail.
REACT 350	Heavy plastic drums connected/restrained by steel cables. Steel cables are main hazard to pedestrians/bicyclists on the face. Tops are 4'-6" off the ground and should not be hazardous to pedestrians/bicyclists.
CAT-350	Similar to guardrail terminal.
Brakemaster 350	Similar to guardrail terminal.
FLEAT-MT	Similar to guardrail terminal.
Sand Modules	Plastic drums weighted with sand. Any spilled sand may affect walking/cycling surface.
ABSORB 350	Plastic barrier shape filled with water. Temporary use only. Any spilled water may freeze, or otherwise wet the walking/cycling surface.

Impact Attenuator Selection

The selected impact attenuator must be compatible with the specific site characteristics. For each category of device, more than one approved system must be allowed for competitive bidding, unless specific approval is made according to 66-1.04(b) of the BDE Manual. Selection of the correct category (pay item) will require comparison and analysis of possible solutions. Factors to consider include:

- type and width of hazard (see above discussion on transitions);
- space, or reserve area, available for installation of the system. The reserve area allows for placement of the barrier and any necessary clearances. (See Figure 4.)
- whether the hazard to be shielded is located in a high- or low-risk impact area;
- initial, maintenance, and restoration costs; and
- ease or difficulty of restoration of the system after impact. The importance of this factor will be related to the traffic and hazard levels at a site. More traffic and higher hazards will make speedy repair or replacement a higher priority.

Figure 5 summarizes the advantages and disadvantages of the impact attenuator principles and categories provided in IDOT specifications. There are many other factors which will influence the selection of a category for a given site. Therefore, the designer should only use this figure as a starting point in the comparison and analysis process for selection of the best category.



Design Speed On Mainline (mph)	Dimensions for Impact Attenuator Reserve Area (feet)								
	Minimum						Prefered		
	Restricted Conditions			Unrestricted Conditions					
	N	L	F	N	L	F	N	L	F
45 or less	7	25	2	9	27	3	12	35	4
over 45	7	38	2	9	40	3	12	45	4

Design Speed On Mainline (km/h)	Dimensions for Impact Attenuator Reserve Area (meters)								
	Minimum						Prefered		
	Restricted Conditions			Unrestricted Conditions					
	N	L	F	N	L	F	N	L	F
70 or less	2.1	7.6	0.6	2.8	8.2	0.9	3.7	10.7	1.2
over 70	2.1	11.6	0.6	2.8	12.2	0.9	3.7	13.7	1.2

RESERVE AREA FOR IMPACT ATTENUATORS

Figure 4

Comparison by Pay Item

OPERATIONAL PRINCIPLE/ (PAY ITEM)	ADVANTAGES	DISADVANTAGES	TYPICAL USES*
ENERGY ABSORBING	*See Figure 3.*	*See Figure 3.*	
Impact Attenuators (Fully Redirective, Narrow) and Impact Attenuators, Temporary (Fully Redirective, Narrow)	1. Prevents encroaching vehicle from traveling behind the impact attenuator. 2. Space efficient. 3. Can fit narrow hazards. 4. Where space permits, connection to a barrier system may allow shielding of wider hazards.	1. Residual capacity after an impact varies among items in this category. 2. Requires anchoring to a slab or pavement. 3. Not suited to wide hazards.	1. Ends of concrete barrier beyond full shoulder width where impacts are expected to be rare. 2. Intermediate width medians, piers. 3. Type D guardrail.
Impact Attenuators (Fully Redirective, Wide), and Impact Attenuators, Temporary (Fully Redirective, Wide)	1. Prevents encroaching vehicle from traveling behind the impact attenuator. 2. IDOT pay items and specifications will cover hazards up to only 90 inches wide. See discussion in "Physical Placement Requirements", under "Transitions." 3. Space efficient.	1. Residual capacity after an impact varies among items in this category. 2. Requires anchoring to a slab or pavement.	1. As above, but for wide hazards such as wide piers, or gore hazards.
Impact Attenuators (Severe Use, Narrow) and Impact Attenuators, Temporary (Severe Use, Narrow)	1. Prevents encroaching vehicle from traveling behind the impact attenuator. 2. May retain significant useful impact capacity after some hits. 3. Space efficient. 4. Can fit narrow hazard.	1. Higher cost than items not requiring severe use characteristics. 2. Requires anchoring to a slab or pavement. 3. Not suited to wide hazards. 4. May rebound a vehicle as the system restores after a frontal hit. This may create secondary collisions with traffic. 5. Requires post impact monitoring to assure that reusable modules are replaced at the end of their service life.	1. Ends of concrete barrier separating opposing traffic where repeated or frequent hits are expected, and/or where it is necessary to keep repair visits and times to a minimum. 2. Narrow medians. 3. Type D guardrail. 4. Roadside concrete barrier or bridge parapet in a temporary application. 5. Other narrow point hazards. This may require limiting the list of devices to those that are free-standing with respect to the hazard.

*See Attachment B for additional information.

Figure 5

Comparison by Pay Item

(CONTINUED)			
OPERATIONAL PRINCIPLE/(PAY ITEM)	**ADVANTAGES**	**DISADVANTAGES**	**TYPICAL USES***
ENERGY ABSORBING	*See Figure 3.*	*See Figure 3.*	
Impact Attenuators (Fully Redirective, Resettable)	1. Requires minimal parts and labor for repairs. Low life-cycle cost where there are occasional to frequent impacts. 2. Prevents encroaching vehicle from getting behind the impact attenuator. 3. Space efficient. 4. Can fit narrow hazard.	1. First cost higher than non-premium system. 2. Not required to self-restore after impact. 3. May require a special barrier detail to transition to a wide hazard.	1. As above, but where impacts are expected on an occasional basis. (At least 1 per 3 years, up to 2 per year, depending on accessibility for repairs and impacts to traffic.)
Impact Attenuators (Severe Use, Wide) and Impact Attenuators, Temporary (Severe Use, Wide)	1. May retain significant useful frontal impact capacity after some hits. 2. Space efficient. 3. Can cover a hazard width up to about 90 inches.	1. Higher cost than items not requiring severe use characteristics. 2. Requires anchoring to a slab or pavement. 3. May rebound a vehicle as the system restores after a frontal hit. This may create secondary collisions with traffic.	1. Piers or gore areas separating opposing traffic where repeated or frequent hits are expected, and/or where it is necessary to keep repair visits and times to a minimum. 2. Narrow medians.
Impact Attenuators (Partially Redirective)	1. Lower cost than fully redirective systems. 2. Suited for direct attachment to Type D guardrail.	1. For narrow hazards. 2. Requires posts to be driven. 3. Lack of reserve impact capacity after a hit.	1. Ends of Type D guardrail separating traffic lanes moving in the same direction, and where impacts are expected to be infrequent. 2. Wide medians, gore areas. 3. Concrete barrier on right side shoulders, or at gores.
Impact Attenuators (Non-Redirective)	See Figure 3 for Sand Modules.	See Figure 3 for Sand Modules.	Point hazards such as piers or sign foundations not near a traffic lane.

Figure 5 (Continued)

*See Attachment B for additional information.

Comparison by Pay Item

(CONTINUED)			
OPERATIONAL PRINCIPLE/(PAY ITEM)	**ADVANTAGES**	**DISADVANTAGES**	**TYPICAL USES***
MOMENTUM TRANSFER	*See Figure 3.*	*See Figure 3.*	
Impact Attenuators Temporary (Non-Redirective)	1. See Figure 5.	1. Area for application must have enough room to accommodate either the sand modules, or the water filled impact attenuator (ABSORB 350). 2. Applies principally where it will shield end of a temporary concrete barrier.	1. Ends of concrete barriers, or other hazards well off the traffic lane, and where it is acceptable to allow a vehicle to encroach behind the device. 2. Standard 701321, Standard 701402.

Figure 5 (Continued)

*See Attachment B for additional information.

Temporary Installations

Access to the work site becomes an additional consideration for temporary installations, especially where temporary concrete barriers are used to close a lane or to channel traffic.

Also, in some cases, such as stage construction of two-lane bridges it may be desirable for the impact attenuator to block the closed lane, reducing the likelihood that an errant vehicle could reach the construction area. These competing needs, access and physical closure of the lane, may be mutually exclusive at some sites where shoulders and right of way are restrictive.

Where construction access can be provided on the shoulders or by other available means (temporary widening, easement, etc), the preferred layout would include concrete barriers and an impact attenuator placed to effectively block the closed lane. The designer should provide necessary plan details to show the positioning of the concrete barrier and impact attenuator devices(s). If sand module impact attenuators are allowed, the specific, required array should be included in the plans along with a notation of the Test Level met by the design. Width restrictions may not allow for angling the array toward traffic. In this case, the array should be installed parallel to the roadway.

Where shoulders of sufficient width or other means of access are not available, the designer can arrange the concrete barriers according to the minimums shown on the Standards, and choose among the various pay items for temporary impact attenuators, as appropriate for the site and traffic. This will allow the Contractor a range of options to weigh for access, cost and maintenance factors.

Engineer of Design and Environment Michael L Hine

State Safety Engineer

Attachments

BDE MEMO 34-06
ATTRIBUTES OF IMPACT ATTENUATORS
ATTACHMENT A

System	Non-Redirective	Partially Redirective	Fully Redirective	Resettable	Self Restoring	Narrow Only	Connects To:	Bidirectional? (Y/N)	Length** (Test Level 3)	Length** (Test Level 2)	Min Width (Out to Out)*	Max Width*	Notes
Quadguard			X			Up to 90"	Generic	Y	23'-11"	12'-9"	2'-7"	90"	Requires paved pad.
Quadguard Elite			X		X	Up to 90"	Generic	Y	35'-6"	23'-11"	2'-7"	90"	Requires paved pad.
Quadguard LMC			X		X	Up to 90"	Generic	Y	35'-6"	23'-11"	3'-7"	90"	Requires paved pad.
CAT-350		X				X	Guardrail or Concrete Barrier	Y	31'-3"	N/A	2'-7"	2'-7"	Installs with driven posts.
REACT 350			X	X	X	Up to 120"	Generic	Y	31'-1"	22'-1"	3'-8" base, & 3' cylinders	120"	Requires paved pad.
Brakemaster 350		X				X	Guardrail or Concrete Barrier	Y	31'-6"	N/A	2'-1"	2'-1"	Installs with driven posts.
TAU-II			X			Up to 96"	Generic	Y	26'-11"	15'-5"	2'-11"	8'-8"	Requires paved pad.
FLEAT MT		X				X	Guardrail or Concrete Barrier	Yes -but intended for wide median	37'-6"	25'	Match Type D Guardrail	Match Type D	Installs with driven posts.
TRACC			X			X	Generic	Y	21'	14'	2'-7"	4'-10"(See Note)	Requires paved pad.
QUEST			X			X	W-beam, Thrie beam, Concrete Barrier, or vertical concrete barrier	Y	18'-10"	N/A	2'-0"	2'-0"	Requires paved pad at front and rear.
SAND MODULES	X						Generic		Varies	Varies	6'	Unlimited	Requires paved pad.
ABSORB 350	X					X	Temporary Concrete Barrier	Y	26'-9"	19'-1/4"	2'-0"	2'-0"	Does not require paved surface.
SCI 100GM			X	X		X	Generic	Y	21'-6"		3'-1 7/16"	3'-1 7/16"	Requires paved pad.

Note: The TRACC may be widened. At it's nominal length and at Test Level 3, the maximum width is 58". Additional width may be gained in approximately 6-1/2" increments by the addition of 2'-4" extension wings.

* The minimum widths shown are nominal out-to-out of the impact attenuator. The various backup systems, transition pieces, etc. are considered part of the impact attenuator, and are to be considered part of the pay item.
Maximum widths are out-to-out if same as minimum, or maximum width of hazard to be shielded, if greater than the shown minimum. This applies to the impact attenuator only. Additional width may be gained by attaching to approved barriers and applying approved flare rates to wide hazards. This application will be limited by available longitudinal space.

** Exclusive of any special transitions or connections.

BDE Memo 34-06
Impact Attenuators -- Permanent Installations
Attachment B

Systems and Allowable Products to Fit Needs	Typical Applications
IMPACT ATTENUATORS *(FULLY REDIRECTIVE, NARROW)* Quadguard Quadguard Elite Quadguard LMC REACT 350 TAU-II family TRACC family SCI-100GM QUEST	Where the expected rate of crashes involving the system are rare to infrequent. (Less than 1 crash per 3 years.) *Narrow Median (< 40') Narrow Hazard, Concrete Barrier, Narrow Pier End of Median Barrier or Type D Rail Alignment or traffic operations do not contribute to added likelihood of run off the road incidents.
IMPACT ATTENUATORS (FULLY REDIRECTIVE, WIDE) Quadguard Quadguard Elite Quadguard LMC React 350 TRACC family TAU-II Universal	*Narrow Median (< 40') Up to 90" Wide Hazard, Sign Base, Pier, etc. Narrow gap between bridges. Alignment or traffic operations do not contribute to added likelihood of run off the road incidents. Hazards where space does not allow development of width transitions from other impact attenuators.
IMPACT ATTENUATORS (FULLY REDIRECTIVE, RESETTABLE) REACT 350 SCI-100GM	Where crashes are expected to be more than 1 per 3 years. Similar locations to Fully Redirective, Narrow.
IMPACT ATTENUATORS (SEVERE USE, NARROW) Quadguard Elite REACT 350 Quadguard LMC	*Narrow Median(<40'), Expect repeated impacts (>2/yr.) Narrow Hazard, Concrete Barrier, Narrow Pier End of Median Barrier or Type D Rail Outside of curves, areas near weaving, lane drops. Near entrances, exits on freeways/expressways. Also appropriate on outside shoulder hazards where repeated impacts and traffic levels make continued capability and ease of repairs critical.
IMPACT ATTENUATORS (SEVERE USE, WIDE) Quadguard Elite REACT 350	*Narrow Median(<40'), Expect repeated impacts Up to 90" Wide Hazard, Sign Base, Pier, etc. Narrow Gap Between Bridges. Outside of curves, areas near weaving, lane drops. Near entrances, exits on freeways/expressways. Also appropriate on outside shoulder hazards where repeated impacts and traffic levels make continued capability and ease of repairs critical. Hazards where space does not allow development of width transitions from other impact attenuators.
IMPACT ATTENUATORS (PARTIALLY REDIRECTIVE) *CAT 350 *Brakemaster 350 *FLEAT MT	Outside Shoulder, Gore Area Narrow Hazard, Pier, Barrier Wall, D Rail Separation of lanes moving in same direction. Expected low frequency of hits.
IMPACT ATTENUATORS (NON-REDIRECTIVE) Fitch Universal Module System Energite III Big Sandy Sand Barrels	Outside Shoulder, Gore Area, Wide Median Sign Support, etc. Separation of lanes moving in same direction, or where there is a wide separation.

Note: The TRACC may be widened. At its nominal length, the maximum width is 58". Additional width may be gained in approximately 6-1/2" increments by the addition of 2'-4" extension wings.

*See figure 6.1 of the 2002 AASHTO Roadside Design Guide. Median Barriers become warranted somewhere between 30' and 50' depending on traffic. This is a reasonable estimate of when we want to avoid having errant vehicles gate through.

Use of standard barrier sections and approved flare rates may allow installation of narrow impact attenuators in advance of wide hazards, depending on space available.

BDE Memo 34-06
Impact Attenuators -- Temporary Installations
Attachment B
(Continued)

Systems and Allowable Products to Fit Needs	Typical Applications
IMPACT ATTENUATORS, TEMPORARY *(FULLY REDIRECTIVE, NARROW)* Quadguard CZ Quadguard LMC Quadguard Elite REACT 350 TRACC Family TAU-II Family SCI-100GM	Locations where the rate of crashes is expected to be less than 1 per 3 years, and first costs control.** *Narrow median locations. Temporary locations where errant vehicles must not encroach behind the device. Head to head traffic. Severe hazards beyond the device.
IMPACT ATTENUATORS, TEMPORARY *(FULLY REDIRECTIVE, WIDE)* Quadguard Elite Quadguard LMC REACT 350 TRACC Family TAU-II Universal	Similar to locations for Fully Redirective, Narrow, but where the hazard is wide.
IMPACT ATTENUATORS, TEMPORARY *(FULLY REDIRECTIVE, RESETTABLE)* REACT 350 SCI-100GM	Where crashes are expected to be more than 1 per 3 years and life cycle costs control.** Similar to locations for Fully Redirective, Narrow.
IMPACT ATTENUATORS, TEMPORARY *(NON-REDIRECTIVE)* Fitch Universal Module System Energite III Big Sandy Sand Barrels ABSORB 350	Temporary locations where errant vehicle may continue behind the crash cushion. Standard 701321, Standard 701402 as site conditions permit.
IMPACT ATTENUATORS, TEMPORARY *(SEVERE USE, NARROW)* Quadguard LMC Quadguard Elite REACT 350	*Narrow median locations. Temporary locations where frequent impacts are expected and/or where access for repairs would create unacceptable traffic control or operational problems. These systems are fully redirective. This must be acceptable at the site.
IMPACT ATTENUATORS, TEMPORARY *(SEVERE USE, WIDE)* Quadguard Elite REACT 350	Similar to locations for Severe Use, Narrow, but where the hazard is wide.

*See figure 6.1 of the 2002 AASHTO Roadside Design Guide. Median Barriers become warranted somewhere between 30' and 50' depending on traffic. That probably is a reasonable estimate of when we want to avoid having errant vehicles gate through.

**Generally, life cycle costs are the responsibility of the Contractor for temporary installations.